# Environmental Conditions on Air Shipments of Livestock



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## PREFACE

In the early 1970's, a large demand for U.S. breeding livestock developed in Asia, Eastern Europe, and the Mideast. Shippers resorted to air charter because of the lack of surface vessels equipped to transport livestock. There was little or no information available to carriers and shippers on the capability of the various types of aircraft equipment and handling methods employed to maintain a healthy environment for livestock in full-planeload lots.

Scientists and engineers of the Science and Education Administration's Agricultural Research unit, veterinarians of the Animal and Plant Health Inspection Service, and the Foreign Agricultural Service were asked by air carriers and livestock exporters to cooperate in obtaining environmental profiles on aircraft shipments of livestock. This is a report on a Government-industry cooperative effort to solve problems associated with transporting livestock overseas by air.

The authors acknowledge the assistance and cooperation of the following companies that provided air passage for researchers and allowed use of their equipment and livestock for this study: Babcock Swine, Inc., Flying Tiger Airline, Inc., Holstein-Friesian Association of America, Illinois Produce International, Inc., J. D. Smith Air Export, Inc., Seaboard World Airlines, and Trans International Airlines.

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# ENVIRONMENTAL CONDITIONS ON AIR SHIPMENTS OF LIVESTOCK

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## ABSTRACT

No sustained adverse environmental conditions were found on four overseas charter shipments of livestock in DC 8 aircraft. The highest temperature of 38 °C was recorded in one cabin area during one flight for a period of several hours. Generally, mean flight temperatures were between 20 and 25 °C, with a 5 to 10 °C temperature buildup when the aircraft air conditioning was shut down for taxiing, takeoff, and landing. Relative humidity levels up to 96 percent also were recorded at these periods, but during most of the flight time, humidity ranged from 10 to 20 percent. No unsafe buildup of carbon dioxide, carbon monoxide, or ammonia gases was measured. The shipments monitored included two planeloads of swine, one load of dairy heifers, and one load of mixed swine and beef heifers. On the four shipments, all animals arrived at their destination in good condition.

KEYWORDS: Livestock, air shipment, export, environmental conditions.

## INTRODUCTION

In 1975, a record number of cattle and swine--44,804--were inspected for export to countries outside North America (Foreign Agricultural Service 1976). It is estimated that up to 90 percent of these livestock were shipped by air, more than twice the amount shipped by air in 1972.

In shipments of U.S. livestock by air freight, the most common aircraft used are the Boeing 707 and the Douglas DC 8 jets. These aircraft were initially designed for passenger traffic and subsequently converted to cargo hauling. Modification to provide additional air conditioning and ventilation for livestock, if at all possible, would be very expensive.

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Animal deaths on air shipments generally are low. On some shipments, however, deaths attributable to environmental conditions have been high. Some of the documented catastrophic examples (Congressional Record 1973) involved young calves that were stacked in double decks and reportedly died from suffocation and overheating.

Available literature on ventilation rates for livestock housing is of little practical help, because it was developed for production conditions. For example, the recommended rate for producing dairy cattle is 0.1 $m^3/s/1000$ kg body weight (Midwest Plan Service 1975). Maximum available ventilation rate for the Boeing 707 is 2.26 $m^3/s$. This rate would allow only forty-five 500-kg animals in a planeload, which is only about half the payload capacity of the aircraft (Boeing Commercial Airplane Group 1972). Records of actual shipments on the DC 8 aircraft indicate that the amount of ventilation available is about 0.05 $m^3/s/1000$ kg of body weight. This rate corresponds with the minimum rate suggested by Stevens et al. (1974) when they developed environmental guidelines for air shipments from existing literature.

British researchers have reported on some of the conditions that exist during air shipments of livestock. Jackson (1974) accompanied a 23-hour flight that carried 43 Hereford cattle, weighing 16,744 kg, from Great Britain to the People's Republic of China. Cabin temperatures on the flight ranged from 15 to 25 $^oC$. Temperatures were highest just before landing.

Williamson (1974) reported difficulty in getting the engineer to reduce cabin temperatures to a comfortable level for cattle in the shipping boxes. He pointed to the importance of familiarizing flightcrews with environmental needs of livestock.

Harris (1974) reported on a shipment of 31 horses from Great Britain to Australia. The horses were sweating when the maximum temperature of 31 $^oC$ was recorded in the midsection of the aircraft.

These reports from Great Britain are not directly applicable to U.S. shipments, since stricter regulations (Statutory Instrument 1973) for the British shipments require room for access to animals in the aircraft and for feeding and watering them during transit. The United States does not have any regulations governing the shipment of livestock by air freight. U.S. precedent (established for rail transport) for humane treatment allows the transport of livestock for 28 to 36 hours before they must be fed and watered. Since jet shipments to the most distant points take less time than that, no feed and water provisions are made. Moreover, the airlines in the United States need a maximum payload to be able to offer profitable and competitive freight service.

The purpose of this study was to obtain detailed information on the environmental conditions on aircraft shipments of livestock:

1. To determine the amount and quality of ventilation available in different types of penning systems in fully loaded jet freighters.

2. To determine operational procedures required to maximize ventilation in existing aircraft.

## PROCEDURES

Four DC 8 charter jet shipments representing different airlines, penning systems, and types of animals were monitored. The shipments and procedures used are described below.

Shipment 1 consisted of 320 pigs, 35 Angus heifers, and 2 Angus bulls shipped from Chicago, Illinois, to Seoul, Korea. A gate-type penning system was used (fig. 1). Table 1 gives the weight and distribution of the animals and their locations in the aircraft. Sensors to measure air velocity and temperature were placed on the cross members of the pen gates at six locations throughout the cargo compartment. Figure 2 shows the pen arrangement and locations of the temperature and humidity sensors. Additional temperature sensors (thermocouples) were placed at eight locations, and a relative humidity sensor placed forward of the aircraft midpoint.

Shipment 2 consisted of 82 Holstein-Friesian heifers, average weight 481 kg, transported from Harrisburg, Pennsylvania, to Tehran, Iran. An igloo penning system was used (fig. 3). Table 2 gives the weight and distribution of the animals and their locations in the aircraft. The aircraft was equipped with an exhaust fan, mounted in the rear door, that was operated when the plane was on the ground. Temperature, humidity, and air velocity were taken at six locations throughout the load as shown in figure 4. We used a Kitagawa gas sampler for periodic measurements of carbon dioxide and ammonia levels in the cabin.

Figure 1.--A gate-type penning system set up in a jet aircraft.

Table 1.--*Load density of pens for shipment 1, from Chicago, Illinois, to Seoul, Korea*

| Pen number 1/ | Number and type of animals | Average weight per animal, kg | Total weight per pen, kg | Space per pen, $m^2$ | Average space per animal, $m^2$ | Density, $kg/m^2$ |
|---|---|---|---|---|---|---|
| 1 | 2 bulls, 5 heifers | 430 | 3,010 | 8.48 | 1.21 | 355 |
| 2 | 51 pigs | 49 | 2,500 | 13.24 | 0.26 | 189 |
| 3 | 51 pigs | 49 | 2,500 | 10.81 | 0.21 | 231 |
| 4 | 55 pigs | 49 | 2,695 | 12.94 | 0.24 | 208 |
| 5 | 48 pigs | 49 | 2,352 | 12.94 | 0.27 | 182 |
| 6 | 85 pigs | 49 | 4,165 | 19.71 | 0.23 | 211 |
| 7 | 6 heifers | 385 | 2,310 | 8.38 | 1.39 | 275 |
| 8 | 12 heifers | 385 | 4,620 | 10.88 | 0.91 | 425 |
| 9 | 12 heifers | 385 | 4,620 | 10.88 | 0.91 | 425 |
| 10 | 30 pigs | 49 | 1,470 | 8.37 | 0.28 | 176 |
| Total | 357 animals | -- | 30,246 | -- | -- | -- |

1/ See figure 2 for location of pen in aircraft.

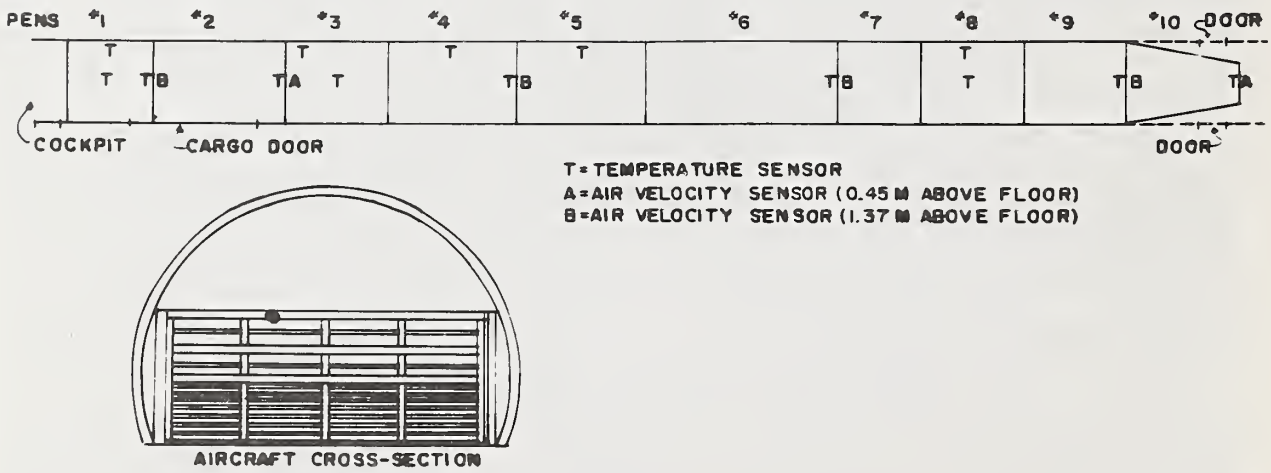


Figure 2.--Pen arrangement, aircraft cross section, and sensor locations for the shipment from Chicago, Illinois, to Seoul, Korea (shipment 1).

Figure 3.--Fiberglass igloos for shipping livestock by air.

Table 2.--*Load density of pens for shipment 2, from Harrisburg, Pennsylvania, to Tehran, Iran*

| Pen number 1/ | Number of animals 2/ | Total weight per pen, kg | Space per pen, $m^2$ | Average space per animal, $m^2$ | Density, $kg/m^2$ |
|---|---|---|---|---|---|
| 1 | 3 | 1,444 | 6.50 | 2.17 | 222 |
| 2 | 6 | 2,888 | 13.47 | 2.25 | 214 |
| 3 | 9 | 4,331 | 13.47 | 1.50 | 321 |
| 4 | 10 | 4,813 | 13.47 | 1.35 | 357 |
| 5 | 10 | 4,813 | 13.47 | 1.35 | 357 |
| 6 | 10 | 4,813 | 13.47 | 1.35 | 357 |
| 7 | 10 | 4,813 | 13.47 | 1.35 | 357 |
| 8 | 10 | 4,813 | 13.47 | 1.35 | 357 |
| 9 | 10 | 4,813 | 13.47 | 1.35 | 357 |
| 10 | 4 | 1,925 | 6.50 | 1.63 | 296 |
| Total | 82 | 39,466 | -- | -- | -- |

1/ See figure 4 for location of pen in aircraft.
2/ All animals were Holstein-Friesian heifers averaging 481 kg each.

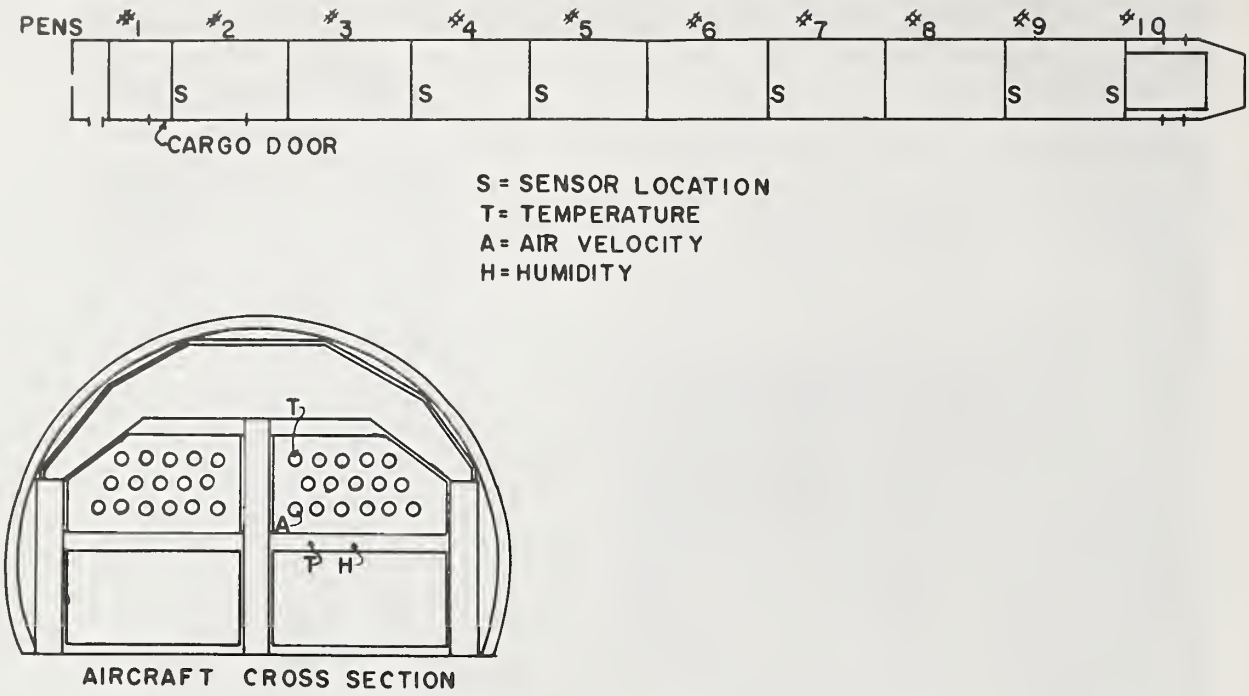


Figure 4.--Pen arrangement, aircraft cross section, and sensor locations for the shipment from Harrisburg, Pennsylvania, to Tehran, Iran (shipment 2).

Shipment 3 was a load of 555 swine (520 gilts weighing from 16 to 93 kg and 35 boars weighing from 63 to 95 kg) shipped from Minneapolis, Minnesota, to Kaohsiung, Taiwan. A double-deck penning system was used (fig. 5). We positioned sensors in six pens to measure temperature, air velocity, and air quality levels of carbon monoxide, carbon dioxide, and ammonia. Relative humidity sensors were located at two positions (fig. 6).

Shipment 4 contained 308 swine (37 boars, average weight 53 kg, and 271 gilts weighing from 15 to 72 kg) shipped from Rochester, Minnesota, to Kaohsiung, Taiwan. The penning system and sensor locations were the same as for shipment 3.

## RESULTS AND DISCUSSION

### Air Temperatures

Air temperatures in the cargo area on the Korea shipment ranged from 6 to 29 $^{o}$C (fig. 7). The lowest temperatures were measured in the front of the cargo area and the highest, about two-thirds of the distance to the rear.

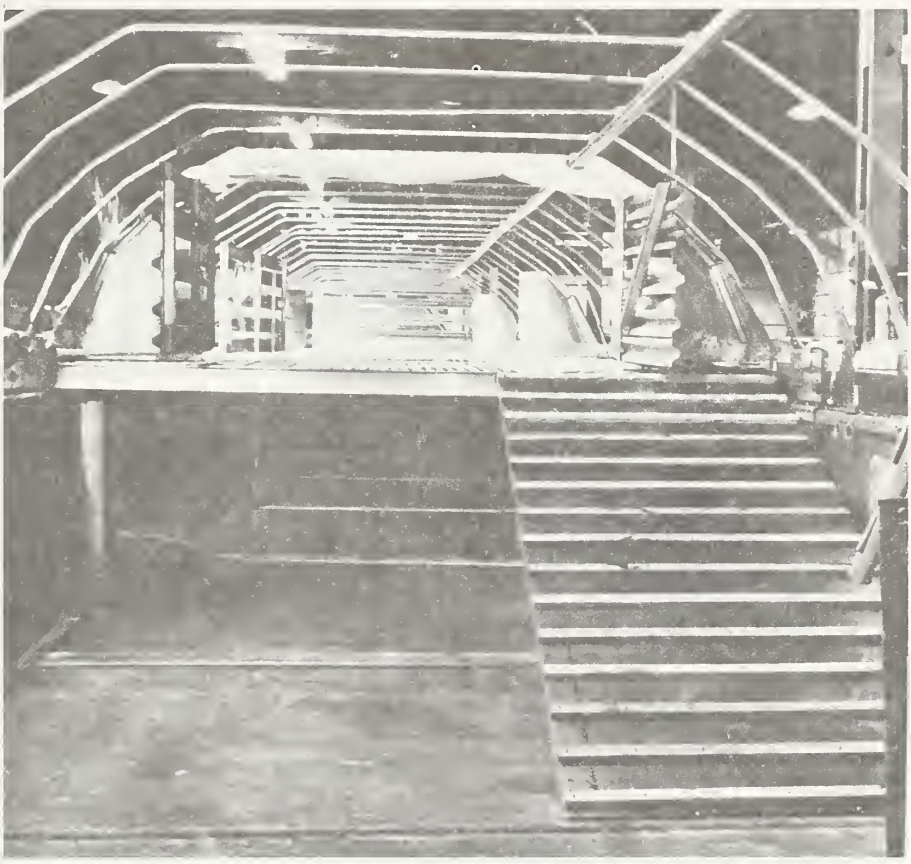

Figure 5.--A double-deck penning system.

During descent and landing at Anchorage and Tokyo, the average temperature increased 6 and 8 °C, respectively. While the plane was on the ground at Anchorage, with the doors open, the temperature rise was as high as 8 °C, even though the outside temperature was 9 °C with no sunshine.

On the shipment to Iran (No. 2), air temperatures in the cargo area ranged from 10 to 31 °C, and the high and low temperature patterns were similar to those observed in other shipments (fig. 8). The average temperature rise during takeoff and landing was about 4 °C. The outside temperatures at John F. Kennedy, Shannon, and Frankfurt airports ranged between 4 and 8 °C, with no sunshine. At times, the temperature difference from front to rear of the cargo area was 20 °C (11 to 31 °C). This difference occurred just after landing before the exhaust fan was turned on.

The average cargo area temperature on the first Taiwan shipment (No. 3) was 22 °C, with a range of 10 to 38 °C (fig. 9). The temperature in the pens on the bottom deck averaged 5 °C higher than on the upper deck. The highest temperature, 38 °C, was recorded after 12 hours' flight time at a location on the left side of the cargo area on the gate dividing pens 8 and 9 (fig. 6).

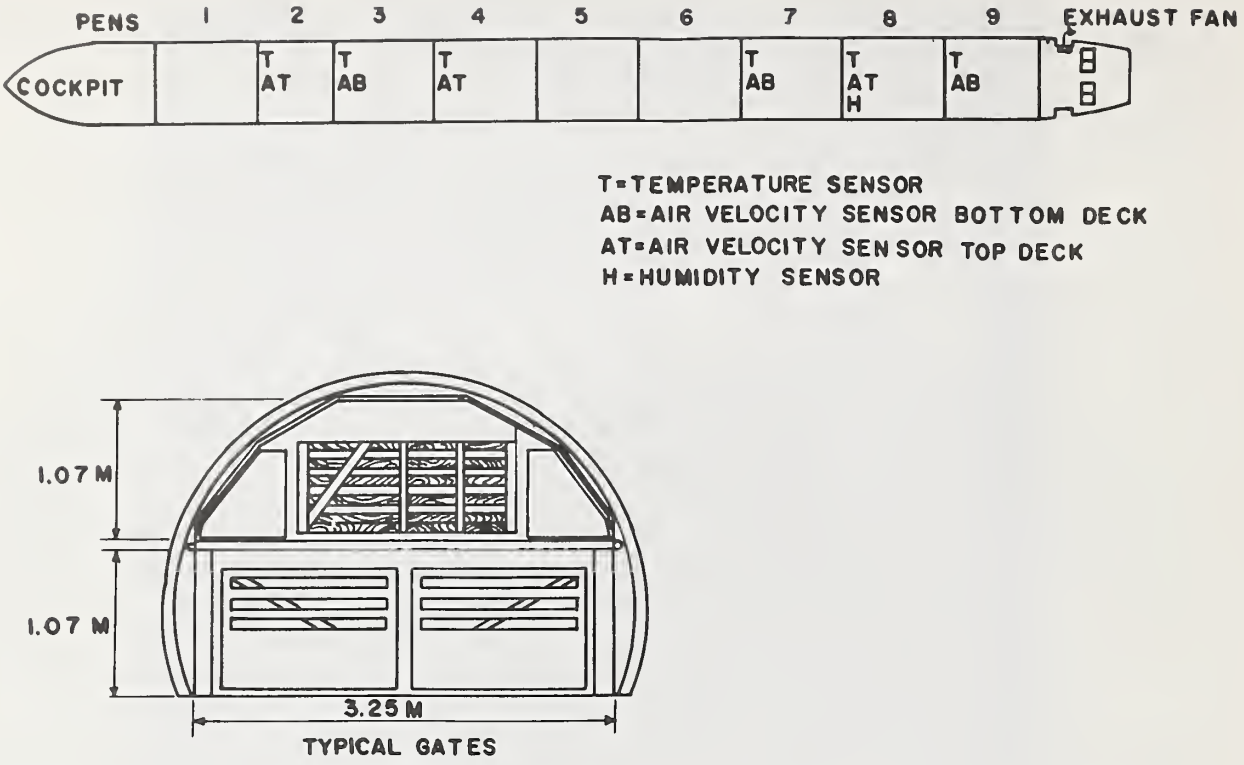


Figure 6.--Pen location, aircraft cross section, and sensor locations for the shipments from Minneapolis, Minnesota, to Kaohsiung, Taiwan (shipments 3 and 4).

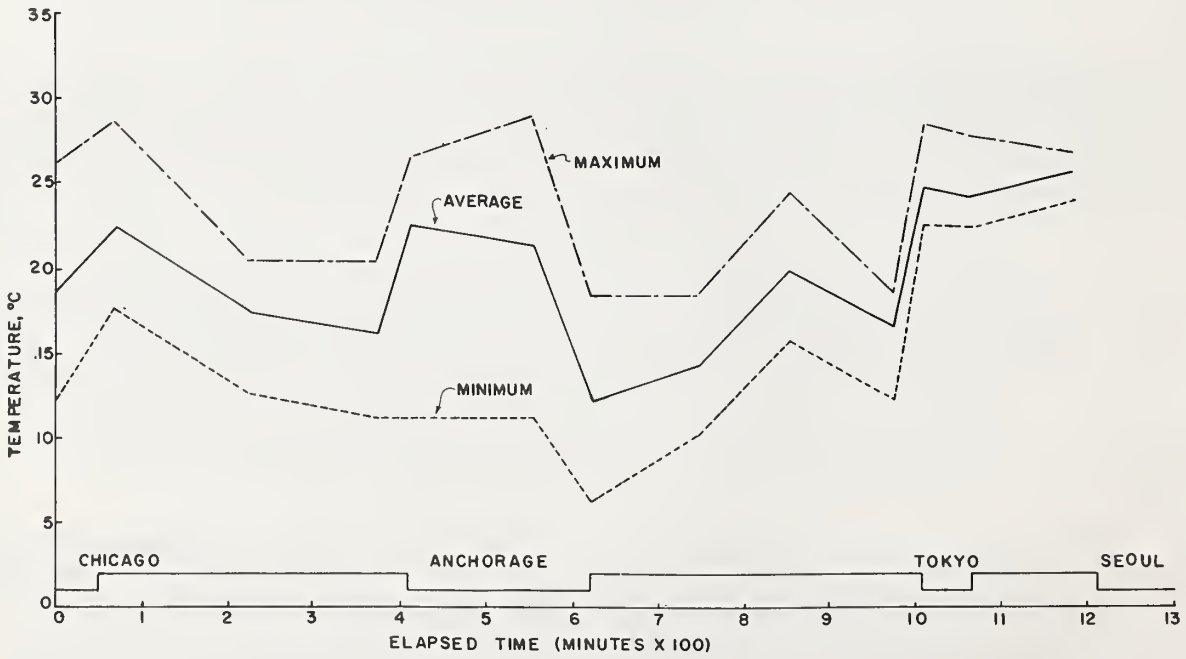


Figure 7.--Profile of temperature in the cargo area on the flight from Chicago, Illinois, to Seoul, Korea (shipment 1).

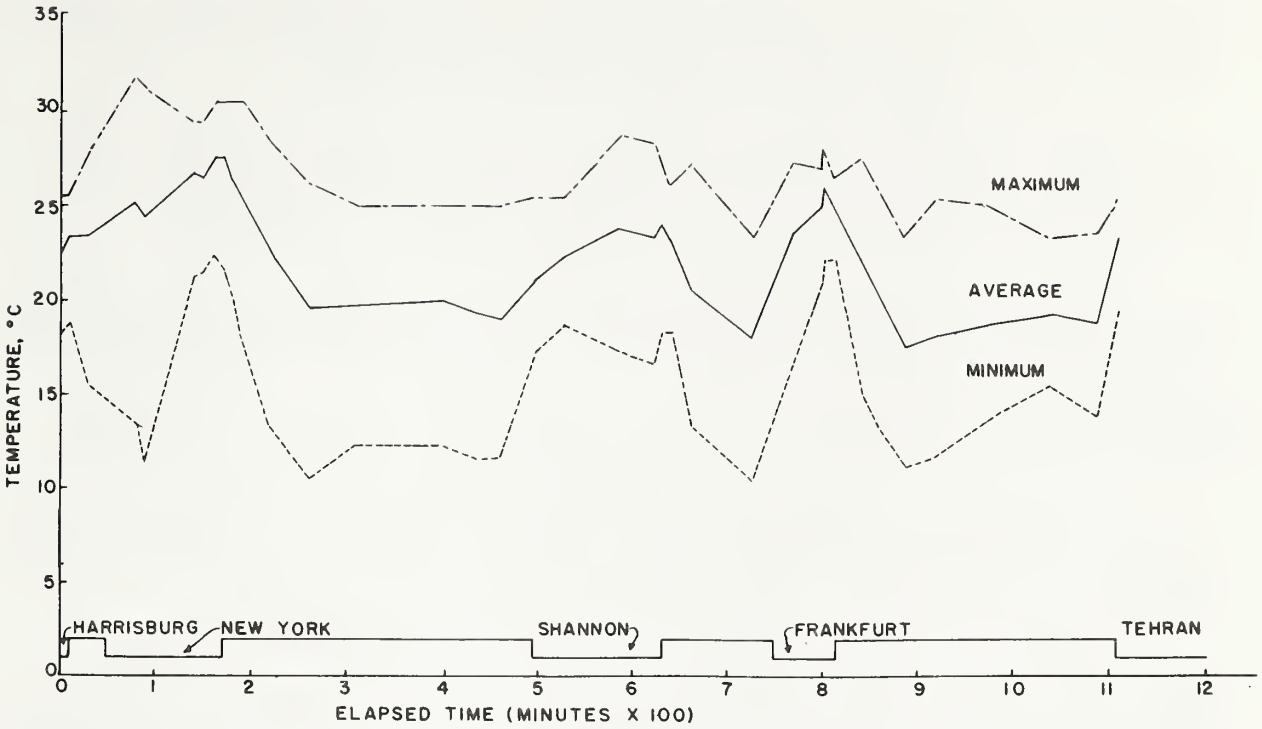


Figure 8.--Profile of temperature in the cargo area on the flight from Harrisburg, Pennsylvania, to Tehran, Iran (shipment 2).

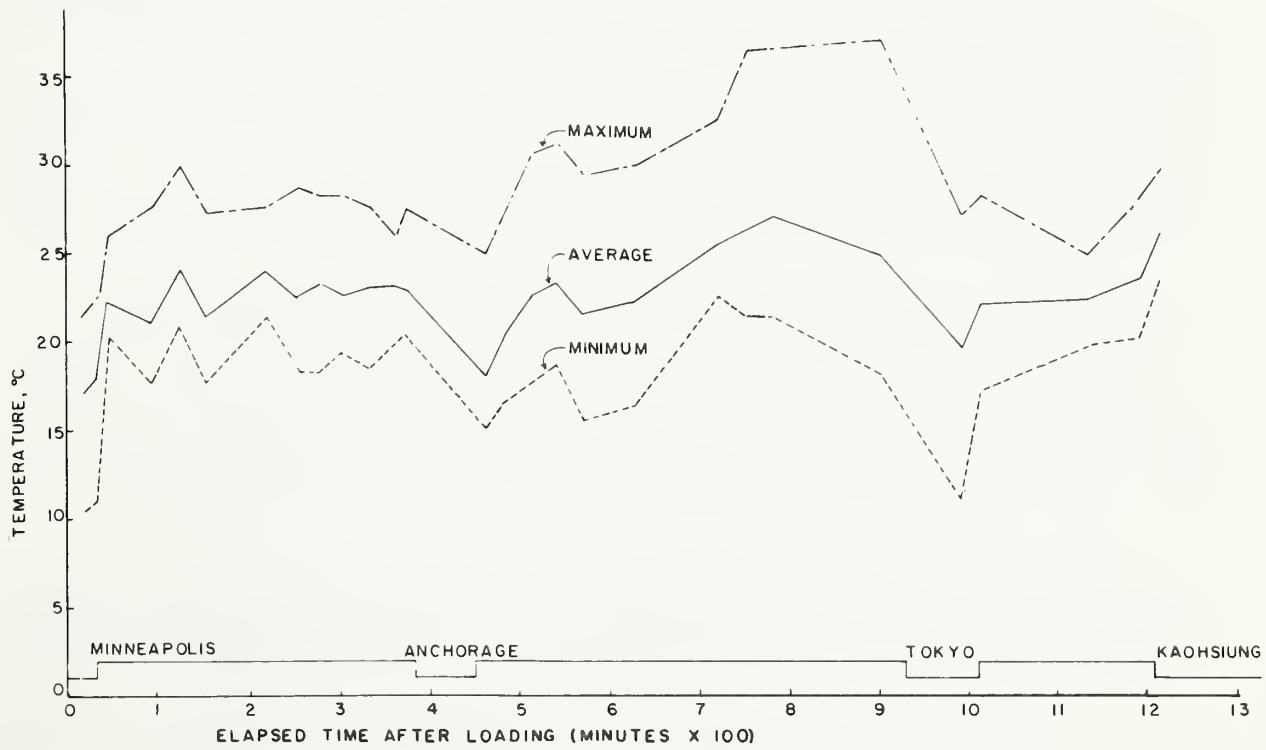


Figure 9.--Profile of temperature in the cargo area on the first flight from Minneapolis, Minnesota, to Kaohsiung, Taiwan (shipment 3).

Temperature in that area remained in the high 30's for several hours before returning to the low 30's for the remainder of the flight. In general, the temperatures at that location were the warmest on the plane.

Temperatures measured on shipment 4, the second Taiwan shipment (fig. 10), were similar to those obtained on the first Taiwan shipment (fig. 9). The only sizable differences were in the minimum temperatures measured at point of origin and at Anchorage, because of lower outside temperatures.

In general, the lowest temperatures were measured in the front of the cargo area and the highest were measured in the rear two-thirds. The locations with the highest temperatures were usually also those with the greatest temperature variation.

Humidity

Relative humidity levels in the cargo area ranged from 10 to 96 percent on all shipments. The humidity profile shown in figure 11 is typical of all shipments.

The highest humidity levels were measured during taxiing, takeoff, and landing when the air-conditioning units were turned off so reserve power would be available in case of an emergency. On cattle shipments, fog developed throughout the aircraft during these periods. Aircrews reported that a real problem sometimes developed when water from the fog condensed on the ceiling.

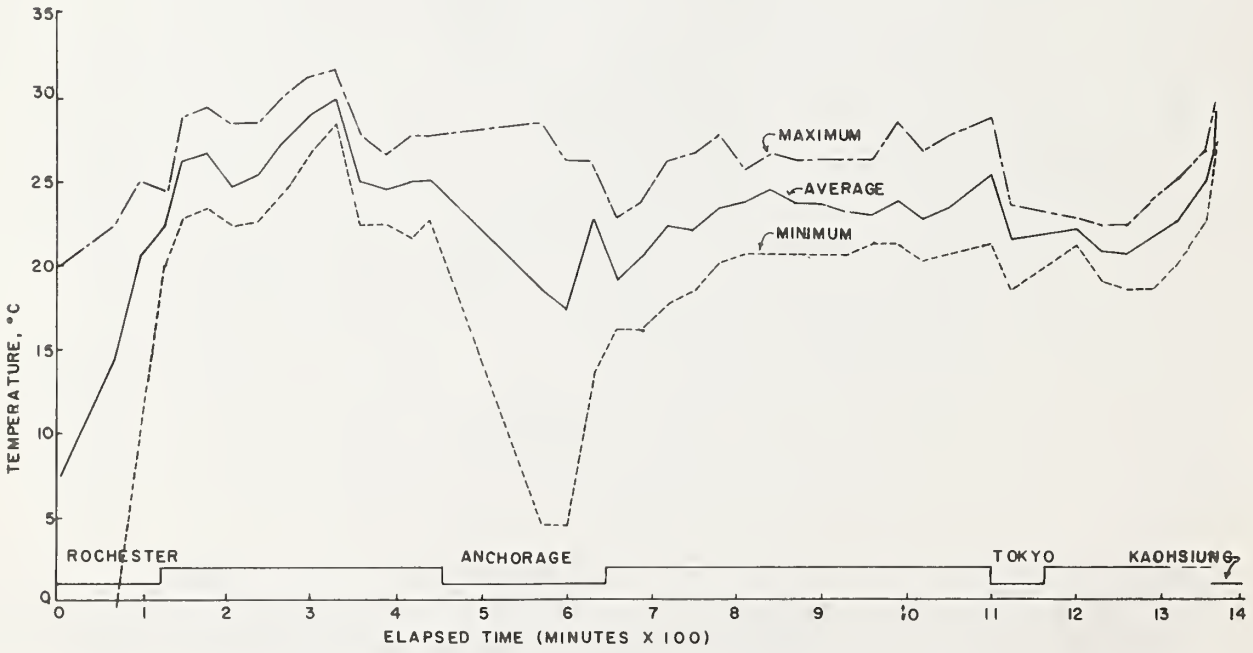


Figure 10.--Profile of temperature in the cargo area on the second flight from Rochester, Minnesota, to Kaohsiung, Taiwan (shipment 4).

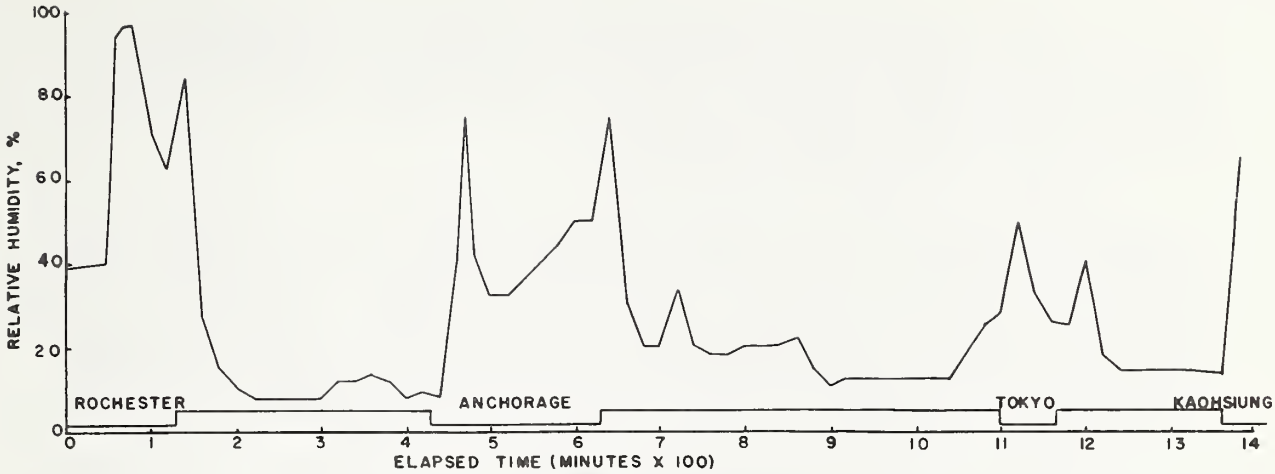


Figure 11.--Humidity profile on the second flight from Rochester, Minnesota, to Kaohsiung, Taiwan (shipment 4).

and on the instrument panels. Humidity levels dropped rapidly during ascent and remained low at cruise altitudes when the air-conditioning system was operating at maximum capacity.

Air Velocity and Gas Concentrations

Air velocities at various locations in the aircraft ranged between 0.05 and 0.5 m/s, with a mean velocity of 0.22 m/s. On the Korea shipment (No. 1), low air velocities were recorded during flights by the sensors placed 0.5 m above the floor, but air velocites were high when the aircraft was on the ground. During loading, a velocity reading of 8.3 m/s was observed. That high reading was caused by a strong wind blowing into the open cargo door. During flight the readings were below 0.3 m/s.

On the Iran shipment (No. 2), the readings were between 0.05 and 0.3 m/s, with a mean of about 0.22 m/s. The gate penning system in the Korea shipment (No. 1) allowed greater air movement than did the igloo penning system, due to more open area in the gates of the penning system. The air velocities through the openings of the gate in both systems were about the same, but the volume of air moved was much greater with the gate than the igloo penning system, as shown by its smaller temperature gradient.

Periodic sampling during flight for carbon dioxide concentration indicated up to a 0.2 percent (2000 ppm) level, which is far below the maximum level recommended by Stevens et al. (1974). No ammonia or carbon monoxide was detected (minimum concentration detectable by the instrument was 10 ppm). During unloading, however, the odor of ammonia could be detected by the people unloading the cattle.

## CONCLUSIONS

Aircraft ventilation systems are sufficient for full-planeloads of livestock, but flightcrews and cargo-handlers must be sensitive to the environmental needs of animals and adjust ventilation controls to meet the varying flight conditions. Penning systems also need to be designed to allow the available ventilation to the animals.

The most critical time during transit is while the aircraft is on the ground for loading, taxiing, and unloading. Since the air-conditioning system on the aircraft is not operating at that time, heat builds up rapidly--especially in direct sunlight. Care should be taken to see that doors are opened and ground air-conditioning units are hooked up immediately after landing. Assurance that the aircraft will receive clearance for takeoff reasonably soon should be obtained before the aircraft doors are closed.

Concentrations of gases did not appear to be a problem on the trips monitored. However, the researchers could not take readings on the manually operated, gas-detecting instruments during taxiing because of safety regulations. High levels of noxious gases are more likely to build up then than at any other time.

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